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220103US-2

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF:

TAKURO SEKIYA ET AL. : EXAMINER:

SERIAL NO: 10/085,204 :

FILED: FEBRUARY 26, 2002 : GROUP ART UNIT:

FOR: SURFACE-EMISSION LASER DIODE OPERABLE IN THE WAVELENGTH BAND OF 1.1-1.7 μm AND OPTICAL TELECOMMUNICATION SYSTEM USING SUCH A LASER DIODE

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

Before examining the captioned patent application, please enter the following Preliminary Amendment:

IN THE SPECIFICATION

Please amend the specification as shown in the Attachment to the amendment.[1] *Clean passages from the amended specification are provided below:*

Amend page 70, lines 4-11 to read as follows:

In the construction of Figure 20, it should be noted that the design wavelength (λ) of the distributed Bragg reflector is 1.5 μm, and the thickness of the Al0.8Ga0.2As layer 18a and the thickness of the GaAs layer 18b are respectively chosen to

[1]In the Attachment to this amendment, underlining and bracketing show the changes introduced into the specification to arrive at the clean text provided here.

110.8 nm and 125.5 nm so as to be equal to $\lambda/4n$, wherein n is a refractive index in the respective layers.

Amend page 110, line 19 through page 111, line 2 to read as follows:

In this embodiment, too, the heterospike buffer layer 18c of intermediate refractive index is provided in the semiconductor Bragg reflector 18 by an AlzGa1-zAs ($0 \le y < z < x \le 1$) layer between the low refractive index layer 18a and the high refractive index layer 18b as already explained with reference to Figure 2. In Figure 27, illustration of the heterospike buffer layer 18c will be omitted for the sake of simplicity.

Amend page 114, lines 4-11 to read as follows:

In the embodiment of Figure 27, it is noted that the GaxIn1-xPyAs1-y ($0 < x \le 1$, $0 < y \le 1$) layer 17 that acts also as an etching stopper layer is provided on the side of upper part reflector 18. Further, a similar GaInP layer 13 is provided on the lower part reflector 12.

Amend page 115, line 20 through page 116, line 3 to read as follows:

It should be noted that such a non-optical recombination elimination layer 13 or 17 constitutes a part of the semiconductor Bragg reflector 12 or 18 in any of the constitution of Figure 1 or 27, and thus, the thickness thereof is set to 1/4

the oscillation wavelength λ as measured in the medium ($\lambda/4$). It is also possible to provide such a non-optical recombination elimination layer in plural numbers.

Amend page 119, line 6 through page 120, line 8 to read as follows:

From the explanation noted above, the laser diode of Figure 27 oscillates efficiently at the wavelength of 1.3 μm similarly to the case of Figure 1. The laser diode of Figure 27 also has advantageous feature of small power consumption and low production cost.

The surface-emission laser diode of Figure 27 can be formed also by an MOCVD process, similarly to the case of Figure 1. However, it is also possible to use an MBE process or other growth process. Further, it is possible to use nitrogen or a nitrogen compound such as NH3 in an activated state.

Furthermore, it is possible to replace the triple quantum well structure (TQW) in the active layer 15 with another structure including different number of quantum wells such as an SQW structure, a DQW structure or an MQW structure. Further, it is possible to use a laser diode of different structure.

By adjusting the composition of the GaInNAs active layer 15a in the surface-emission laser diode of Figure 1, it becomes possible to realize a surface-emission laser diode of the 1.55 μm band and further the 1.7 μm band. In the present invention,

the GaInNAs active layer may contain other III-V elements such as Tl, Sb, P, and the like. Further, it is also possible to construct a surface-emission laser diode of 1.3 μm band on a GaAs substrate by using GaAsSb for the active layer.

Amend page 130, line 6 through page 133, line 9 to read as follows:

Figure 32 shows an example of the semiconductor light-emitting device formed by providing such a carrier purging process. In Figure 32, those parts corresponding to the parts described previously are designated by the same reference numerals and the description thereof will be omitted.

Thus, it can be seen that the Al-containing first semiconductor layer 202, the first lower part intermediate layer 601, the second lower part intermediate layer 602, the N-containing active layer 204, the upper part intermediate layer 203, and the second semiconductor layer 205 are stacked consecutively the on substrate 201 in Figure 32.

In forming the structure of Figure 32, the crystal growth is carried out by an epitaxial growth apparatus by using an organic-metal Al source and an organic nitrogen source material. In the case, the growth interruption process is provided before the start of growth of the second lower part intermediate layer 602 but after the growth of the first lower part intermediate layer 601. During the growth interruption process, the part of

the growth chamber that may make a contact with the nitrogen compound source material or the impurity in the nitrogen compound source material is purged by a hydrogen gas used as the carrier gas, such that the residual Al source material or residual Al reactant or residual Al compound or residual Al is removed.

Figure 33 shows the result of measurement of the depth profile of Al concentration on a semiconductor light-emitting device in which there has been provided a growth interruption between the first lower part intermediate layer 601 and the second lower part intermediate layer 602 and a purging process was conducted for 60 seconds.

Figure 33 is referred to. It can be seen that the Al concentration in the active layer 204 is reduced to 3×10^{17} cm^{-3} or less as a result of such a growth interruption process and purging process. This value of Al concentration is the same degree as the Al concentration in the intermediate layers 601 and 602.

Figure 34 shows the depth profile of nitrogen and oxygen for the device of Figure 32.

Figure 34 is referred to. It can be seen that the oxygen concentration in the active layer 204 is reduced to 1×10^{17} cm^{-3}, which is a background level. The oxygen peak appearing in the lower part intermediate layer 601 or 602 in Figure 34 is interpreted as showing oxygen segregation to the growth

interruption interface as a result of interruption of growth. Thus, it is preferable to conduct the growth interruption period after the termination of the growth of the semiconductor layer containing Al but before the growth termination of the non-optical recombination elimination layer, in the case there is provided a growth interruption and purging process. In the non-optical recombination elimination layer, it is possible to increase the bandgap energy as compared with the quantum well active layer or barrier layer, and the adversary effect of the non-optical recombination caused by the oxygen segregated to the growth interruption interface is effectively suppressed when career injection is made into the active layer. The constitution that uses the non-optical recombination elimination layer provides a particularly advantageous effect in the case of using an active layer containing nitrogen.

In the semiconductor light-emitting device of Figure 32, the impurity concentration level of Al and oxygen in the nitrogen-containing active layer 204 is reduced successfully by interrupting the growth process between the first lower part intermediate layer 601 and the second lower part intermediate layer 602 and by conducting a purging process for 60 minutes. In this way, the optical efficacy of the active layer 204 was effectively improved.

Amend page 134, lines 8-21 to read as follows:

Further, it is also possible to carry out the purging process while continuing the growth of the intermediate layer. In the constitution of Figure 27, for example, the non-optical recombination elimination layer 13 is provided between the N-containing active layer 15 and the reflector 12 formed of the AlGaAs material containing Al. Thereby, the distance between the N-containing active layer 15 and the Al-containing layer is increased, and it is possible to increase the duration of the purging process in the case the purging process is conducted simultaneously to the growth. In such a case, it is advantageous to decrease the growth rate and increase the purging time.

Amend page 304, line 18 through page 305, line 9 to read as follows:

The present application is based on Japanese priority applications

- No. 2001-050145 filed on February 26, 2001,
- No. 2001-050171 filed on February 26, 2001,
- No. 2001-050083 filed on February 26, 2001,
- No. 2001-051253 filed on February 26, 2001,
- No. 2001-051256 filed on February 26, 2001,
- No. 2001-051266 filed on February 26, 2001,
- No. 2001-053213 filed on February 27, 2001,
- No. 2001-053218 filed on February 27, 2001,

- No. 2001-053200 filed on February 27, 2001,
- No. 2002-50548 filed on February 26, 2002,
- No. 2001-053190 filed on February 27, 2001,
- No. 2001-053225 filed on February 27, 2001,
- No. 2001-073767 filed on March 15, 2001,
- No. 2001-090711 filed on March 27, 2001,
- No. 2002-019748 filed on January 29, 2002,
- No. 2002-033590 filed on February 12, 2002,

the entire contents of which are hereby incorporated by reference.

IN THE CLAIMS

Please amend Claim 1 as shown in the Attachment to this amendment.[2] *A clean claim is provided below:*

1. (Amended) A distributed Bragg reflector, comprising:

a first semiconductor layer having a first, larger refractive index;

a second semiconductor layer having a second, lower refractive index,

said first and second semiconductor layers being stacked alternately; and

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[2]In the Attachment to this amendment, underlining and bracketing show the changes introduced into the previously-pending claims to arrive at the clean claims.

a material layer, provided between said first semiconductor layer and said second semiconductor layer, having a thickness equal to or larger than 5 nm but equal to or smaller than 50 nm, and having a refractive index intermediate between said first and second refractive indices;

wherein said distributed Bragg reflector is tuned to a wavelength of 1.1 μm or longer.

REMARKS

Favorable consideration of the above-identified patent application in light of the foregoing amendment is respectfully requested. The present amendment corrects drawing references and other typographical/clerical errors in the specification, and amends Claim 1 to be clearer and not to narrow the claim or for any other reason related to patentability.

An early and favorable action on the merits is respectfully requested.

Respectfully submitted,

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Marked-Up Copy
Serial No. 10/085,204
Amendment Filed on: 4-1-02

ATTACHMENT

SHOWING CHANGES TO APPLICATION

IN THE SPECIFICATION

Amend page 70, lines 4-11 to read as follows:

In the construction of Figure 20, it should be noted that the design wavelength (λ) of the distributed Bragg reflector is 1.5 μm, and the thickness of the Al0.8Ga0.2As layer 18a and the thickness of the GaAs layer 18b are respectively chosen to 110.8 nm and [12.55] 125.5 nm so as to be equal to λ/4n, wherein n is a refractive index in the respective layers.

Amend page 110, line 19 through page 111, line 2 to read as follows:

In this embodiment, too, the heterospike buffer layer 18c of intermediate refractive index is provided in the semiconductor Bragg reflector 18 by an AlzGa1-zAs ($0 \leq y < z < x \leq 1$) layer between the low refractive index layer 18a and the high refractive index layer 18b as already explained with reference to Figure 2. In Figure [10] 27, illustration of the heterospike buffer layer 18c will be omitted for the sake of simplicity.

Amend page 114, lines 4-11 to read as follows:

In the embodiment of Figure [10] 27, it is noted that the GaxIn1-xPyAs1-y ($0<x\leq1$, $0<y\leq1$) layer 17 that acts also as an etching stopper layer is provided on the side of upper part reflector 18. Further, a similar GaInP layer 13 is provided on the lower part reflector 12.

Amend page 115, line 20 through page 116, line 3 to read as follows:

It should be noted that such a non-optical recombination elimination layer 13 or 17 constitutes a part of the semiconductor Bragg reflector 12 or 18 in any of the constitution of Figure 1 or [10] 27, and thus, the thickness thereof is set to 1/4 the oscillation wavelength λ as measured in the medium ($\lambda/4$). It is also possible to provide such a non-optical recombination elimination layer in plural numbers.

Amend page 119, line 6 through page 120, line 8 to read as follows:

From the explanation noted above, the laser diode of Figure [10] 27 oscillates efficiently at the wavelength of 1.3 μm similarly to the case of Figure 1. The laser diode of Figure [10] 27 also has advantageous feature of small power consumption and low production cost.

The surface-emission laser diode of Figure [10] 27 can be formed also by an MOCVD process, similarly to the case of Figure

1. However, it is also possible to use an MBE process or other growth process. Further, it is possible to use nitrogen or a nitrogen compound such as NH3 in an activated state.

Furthermore, it is possible to replace the triple quantum well structure (TQW) in the active layer 15 with another structure including different number of quantum wells such as an SQW structure, a DQW structure or an MQW structure. Further, it is possible to use a laser diode of different structure.

By adjusting the composition of the GaInNAs active layer 15a in the surface-emission laser diode of Figure [10] 1, it becomes possible to realize a surface-emission laser diode of the 1.55 μm band and further the 1.7 μm band. In the present invention, the GaInNAs active layer may contain other III-V elements such as Tl, Sb, P, and the like. Further, it is also possible to construct a surface-emission laser diode of 1.3 μm band on a GaAs substrate by using GaAsSb for the active layer.

Amend page 130, line 6 through page 133, line 9 to read as follows:

Figure [15] 32 shows an example of the semiconductor light-emitting device formed by providing such a carrier purging process. In Figure [15] 32, those parts corresponding to the parts described previously are designated by the same reference numerals and the description thereof will be omitted.

Thus, it can be seen that the Al-containing first semiconductor layer 202, the first lower part intermediate layer 601, the second lower part intermediate layer 602, the N-containing active layer 204, the upper part intermediate layer 203, and the second semiconductor layer 205 are stacked consecutively the on substrate 201 in Figure [15] 32.

In forming the structure of Figure [15] 32, the crystal growth is carried out by an epitaxial growth apparatus by using an organic-metal Al source and an organic nitrogen source material. In the case, the growth interruption process is provided before the start of growth of the second lower part intermediate layer 602 but after the growth of the first lower part intermediate layer 601. During the growth interruption process, the part of the growth chamber that may make a contact with the nitrogen compound source material or the impurity in the nitrogen compound source material is purged by a hydrogen gas used as the carrier gas, such that the residual Al source material or residual Al reactant or residual Al compound or residual Al is removed.

Figure [16] 33 shows the result of measurement of the depth profile of Al concentration on a semiconductor light-emitting device in which there has been provided a growth interruption between the first lower part intermediate layer 601 and the

second lower part intermediate layer 602 and a purging process was conducted for 60 seconds.

Figure [16] <u>33</u> is referred to. It can be seen that the Al concentration in the active layer 204 is reduced to 3 x 10^{17} cm^{-3} or less as a result of such a growth interruption process and purging process. This value of Al concentration is the same degree as the Al concentration in the intermediate layers 601 and 602.

Figure [17] <u>34</u> shows the depth profile of nitrogen and oxygen for the device of Figure [15] <u>32</u>.

Figure [17] <u>34</u> is referred to. It can be seen that the oxygen concentration in the active layer 204 is reduced to 1 x 10^{17} cm^{-3}, which is a background level. The oxygen peak appearing in the lower part intermediate layer 601 or 602 in Figure [17] <u>34</u> is interpreted as showing oxygen segregation to the growth interruption interface as a result of interruption of growth. Thus, it is preferable to conduct the growth interruption period after the termination of the growth of the semiconductor layer containing Al but before the growth termination of the non-optical recombination elimination layer, in the case there is provided a growth interruption and purging process. In the non-optical recombination elimination layer, it is possible to increase the bandgap energy as compared with the quantum well active layer or barrier layer, and the adversary effect of the

No. 2002-033590 filed on February 12, 2002, the entire contents of which are hereby incorporated by reference.

IN THE CLAIMS

1. (Amended) A distributed Bragg reflector, comprising:

a first semiconductor layer having a first, larger refractive index;

a second semiconductor layer having a second, lower refractive index,

said first and second semiconductor layers being stacked alternately[,]; and

a material layer, provided between said first semiconductor layer and said second semiconductor layer, having a thickness equal to or larger than 5 nm but equal to or smaller than 50 nm, and having a refractive index intermediate between said first and second refractive indices; [,]

wherein said distributed Bragg reflector [being] is tuned to a wavelength of 1.1 μm or longer[,

wherein there is provided a material layer having a refractive index intermediate between said first refractive index and said second refractive index,

said material layer having a thickness equal to or larger than 5 nm but equal to or smaller than 50 nm].

the duration of the purging process in the case the purging process is conducted simultaneously to the growth. In such a case, it is advantageous to decrease the growth rate and increase the purging time.

Amend page 304, line 18 through page 305, line 9 to read as follows:

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- No. 2001-053213 filed on February 27, 2001,
- No. 2001-053218 filed on February 27, 2001,
- No. 2001-053200 filed on February 27, 2001,
- No. [2001-053200] 2002-50548 filed on [February 27, 2001] February 26, 2002,
- No. 2001-053190 filed on February 27, 2001,
- No. 2001-053225 filed on February 27, 2001,
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